Geochemical and Mineralogical Maps, with Interpretation, for Soils of the Conterminous United States

Arsenic (As)

By David B. Smith, Federico Solano, Laurel G. Woodruff, and William F. Cannon

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Disclaimer

The purpose of these interpretive discussions is to provide a perspective on regional- and national-scale variations in element and mineral distributions in soils and their likely causes. The significant spatial variations shown by most elements and minerals can commonly be attributed to geologic sources in underlying parent materials, but other spatial variations seem clearly related to additional factors such as climate, the age of soils, transported source material, and anthropogenic influences. We attempt to distinguish the influence of these various factors on a regional and national scale. Numerous more local features might similarly be related to these same factors, but these features also have some probability of being an artifact of a random sampling of variable compositions, so that there is some probability of samples with similar compositions occurring in clusters of two or more adjacent sites by chance. Distinguishing such random occurrences from true variability is beyond the scope of the data from which these maps are constructed. Some caution, therefore, is advisable in interpreting the significance of these more local features unless some unique sources or processes can clearly be related to them.

This document was downloaded from https://pubs.usgs.gov/sir/xxxxxxxx.

The maps and statistical graphics in this document were derived from data published in U.S. Geoolgical Survey Data Series 801 (Smith and others, 2013), downloadable from https://pubs.usgs.gov/ds/801.

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Arsenic (As)

Arsenic (As) is a metalloid, meaning this element has properties between that of a typical metal and nonmetal. It is a well-known poison and its toxic properties have led to its use in pesticides and insecticides. It is also a known carcinogen. **Arsenic's** toxic properties have made its compounds useful in medicine for the treatment of syphilis, cancer, and psoriasis. **Arsenic** is also used in the manufacture of semiconductors and pyrotechnics (**As** sulfide produces a brilliant white light). **Arsenic** has not been determined to be required for any essential biochemical process in humans. More information about the toxicity of **As** (or other elements and substances) and its potential negative human health impacts can be found at the Agency for Toxic Substances and Disease Registry *(ATSDR) website*, or click to *download a fact sheet* about **As**.

Arsenic has a strong affinity for *sulfur (S)* and the most common **As** mineral is arsenopyrite (FeAsS). In silicate minerals, **As** can substitute for *iron (Fe)* and *aluminum (Al)* to some extent. As a result, **As** can occur in silicate minerals such as *feldspar*. **Arsenic** can also replace *phosphorus (P)* in phosphate minerals such as apatite [$Ca_5(PO_4,CO_3)_3(F,OH,Cl)$]. In soils, **As** can sorb onto Fe oxides and hydroxides, *clay* minerals, and organic matter.

The distribution of mineral resource deposits with **As** as a commodity (major or minor) in the United States, extracted from the U.S. Geological Survey (USGS) Mineral Resource Data System *(MRDS) website*, can be seen in Figure 1. Statistics and information on the worldwide supply of, demand for, and flow of **As-**containing materials are available through the USGS National Minerals Information Center *(NMIC) website*.

The average abundance of **As** in the upper continental crust is estimated to be about 5.7 milligrams per kilogram (mg/kg) (Hu and Gao, 2008). Among the common rock types, shale contains the highest **As** with concentrations averaging about 13 mg/kg. Other common sedimentary and igneous rocks have concentrations ranging from 0.5 to 3 mg/kg.

In our data, the median **As** concentration for the top 0- to 5- cm layer and for the soil A horizon is 5.2 mg/kg. **Arsenic** in the soil C horizon is only marginally higher with a median concentration of 5.7 mg/kg (see the summary statistics, below). In general, the geochemical maps for the three sample types are quite similar for **As**.

The distribution of **As** in soils of the conterminous United States is primarily controlled by the composition of underlying soil parent materials. Areas of elevated **As** concentrations include:

- Eastern Montana, North Dakota, South Dakota, eastern Nebraska, eastern Kansas, southern Iowa, northern Missouri, Illinois, Indiana, Ohio, Kentucky, and Pennsylvania where soil parent materials are dominantly marine shale, clayey till, or glacial deposits containing a significant amount of shale;
- The Texas Blackland Prairie (USDA, 2006) of north-central Texas where soil parent materials are chalk, *clay*, and marl with *pyrite* nodules common in places;
- Eastern Texas where soil developed on a bedrock unit called the Claiborne Group that consists of marine mudstone with accessory **As**-bearing *pyrite*; and

- Western Montana, Nevada, central and northern Arizona, and south-central Colorado where **As** is present as a constituent of sulfide minerals in areas of historical or current mining activities. Soils in these areas may be formed on mineralized bedrock containing elevated concentrations of **As**. In areas of extensive mining and mineral processing, it is also possible that there may be a component of **As** contamination from these activities superimposed on elevated background concentrations.

The Gulf and Atlantic Coastal Plain (Fenneman and Johnson, 1946) is bisected by the Southern Mississippi River Alluvium and the Southern Mississippi Valley Loess (USDA, 2006). Alluvial sediments have deposited in the Mississippi River valley as the river flooded in recent geologic time. When these sediments dried, winds picked up the fine material and deposited it in thick loess sheets, mainly along the east side of the river valley. The youngest loess sheets are about 10,000 years old. A pattern of higher **As** concentrations in soils developed on these young sediments reflects long-range transport of **As**-bearing material from the upper part of the Mississippi River drainage basin.

Areas of relatively low **As** concentrations include:

- Atlantic Coastal Plain (Fenneman and Johnson, 1946) where parent materials are dominantly *quartz*-rich sedimentary rocks and unconsolidated sediments;
- Nebraska Sand Hills (USDA, 2006) where soil parent materials are *quartz*- and *plagioclase*-rich sand dunes and sand sheets;
- Parts of the Southern High Plains (USDA, 2006) of Texas and New Mexico where soil parent materials consist of *quartz*-rich eolian sands and alluvial sediments;
- Adirondack highlands (Fenneman and Johnson, 1946) , northern New York, where parent materials are igneous and metamorphic rocks; and
- Northern and western Michigan where parent materials are comprised of *quartz*-rich glacial deposits.

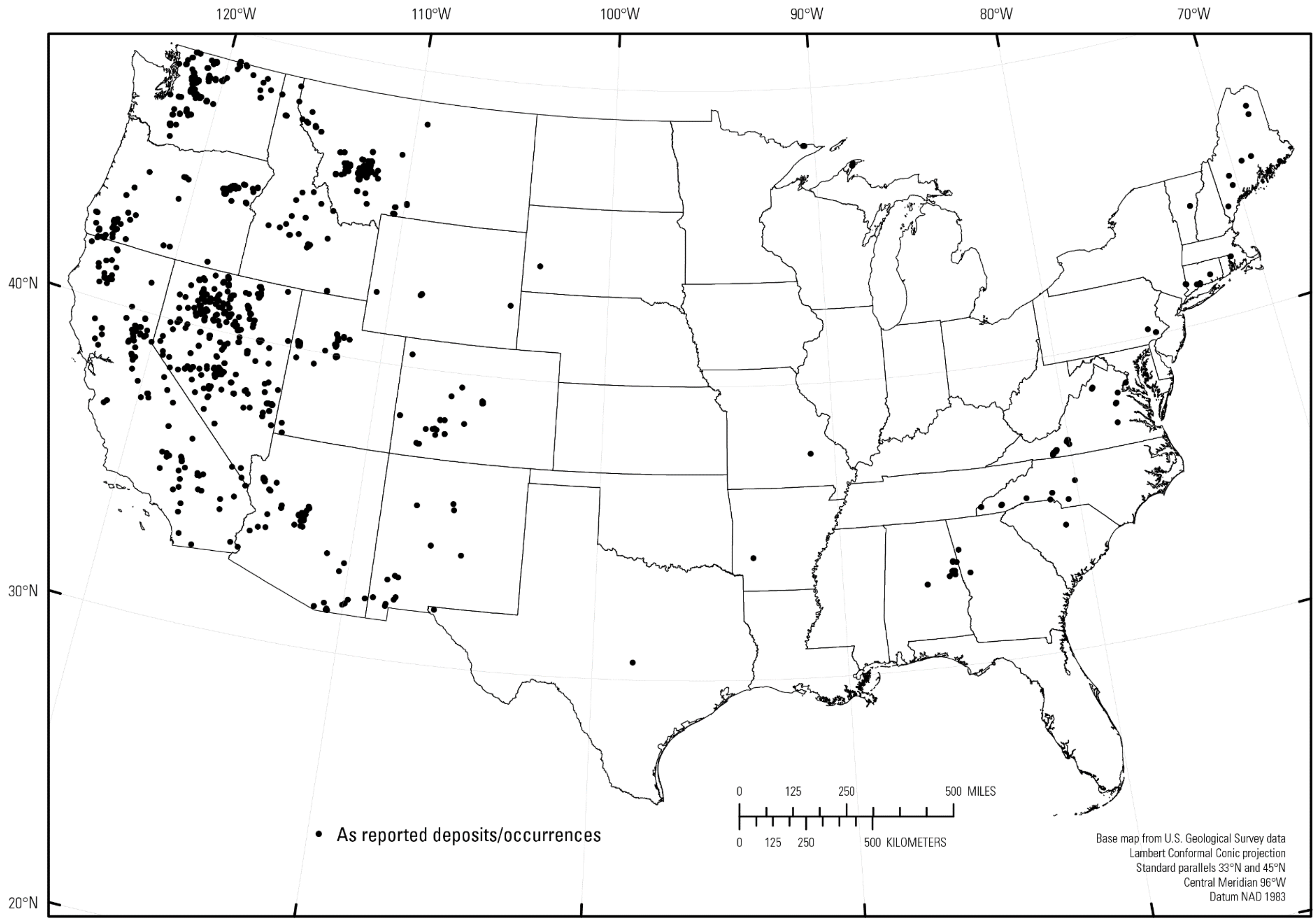
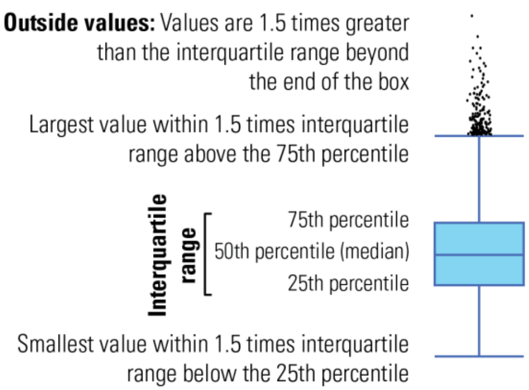


Figure 1. Location of reported deposits or occurrences of Arsenic (As) in the conterminous United States, as derived from data available at the U.S. Geological Survey (USGS) Mineral Resource Data System *(MRDS) website*.

	Units	Top 0- to 5 cm	A horizon	C horizon
No. of samples		4,841	4,813	4,780
LLD	mg/kg	0.6	0.6	0.6
No. below LLD		56	67	73
Minimum	mg/kg	<0.6	<0.6	<0.6
5%	mg/kg	1.4	1.3	1.3
25%	mg/kg	3.1	3.1	3.4
50%	mg/kg	5.2	5.2	5.7
75%	mg/kg	7.6	7.8	8.4
95%	mg/kg	13.1	13.1	15.7
Maximum	mg/kg	830	1,110	397
MAD	mg/kg	3.26	3.41	3.56
Robust CV	%	62.7	65.6	62.4

EXPLANATION



LLD: Lower Limit of Determination
MAD: Median Absolute Deviation
Robust CV: Robust Coefficient of Variation
mg/kg: milligrams per kilogram
cm: centimeter

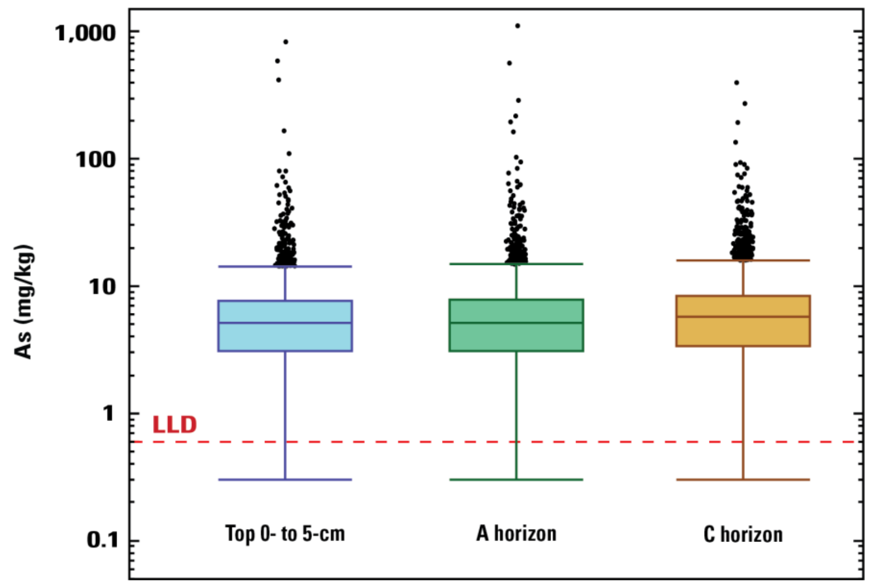


Figure 2. Summary statistics for the distribution of Arsenic (As) in the top 0- to 5-cm soil layer, the soil A horizon, and the soil C horizon in the conterminous United States.

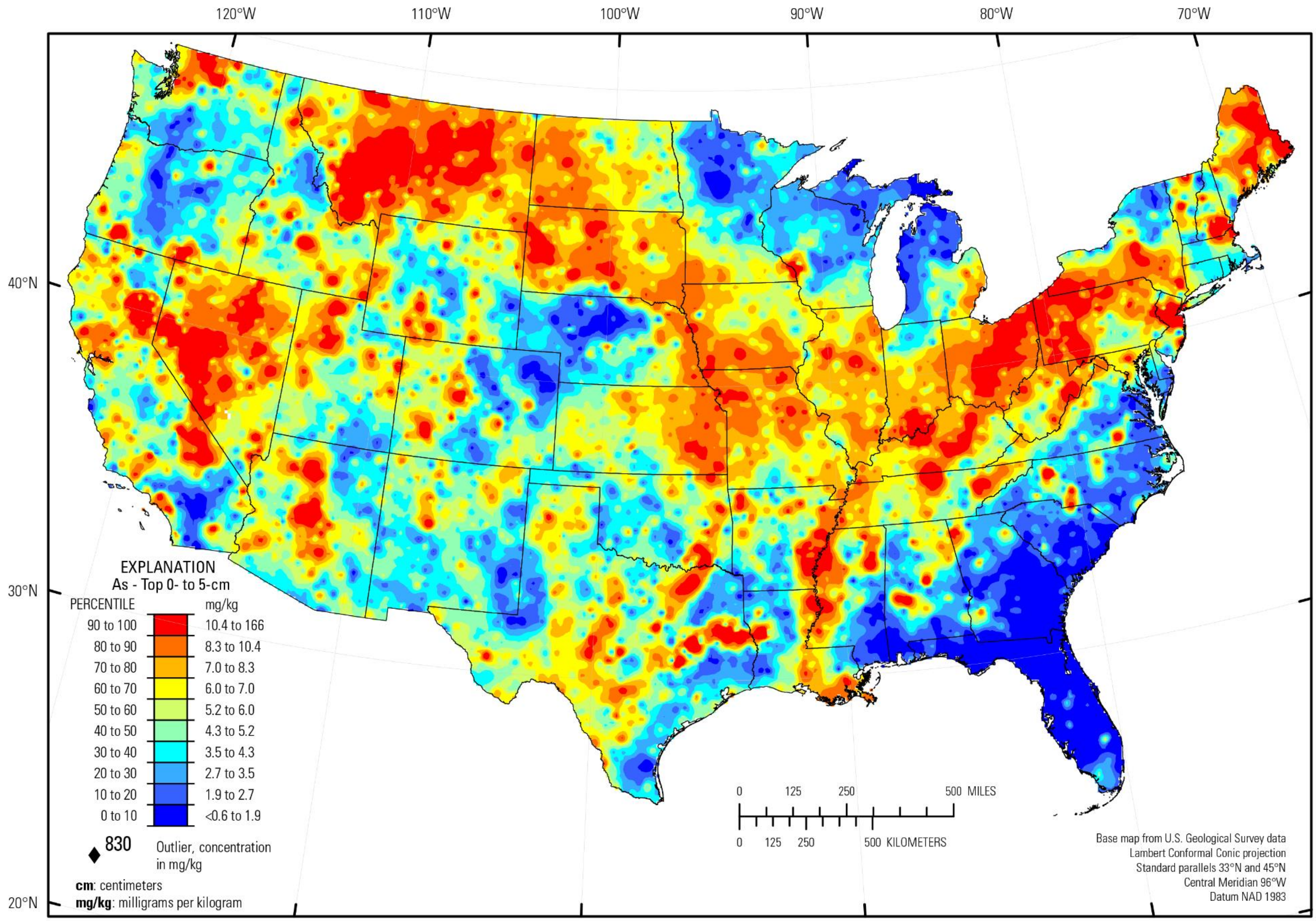


Figure 3. Distribution of Arsenic (As) in the top 0- to 5-cm soil layer, conterminous United States.

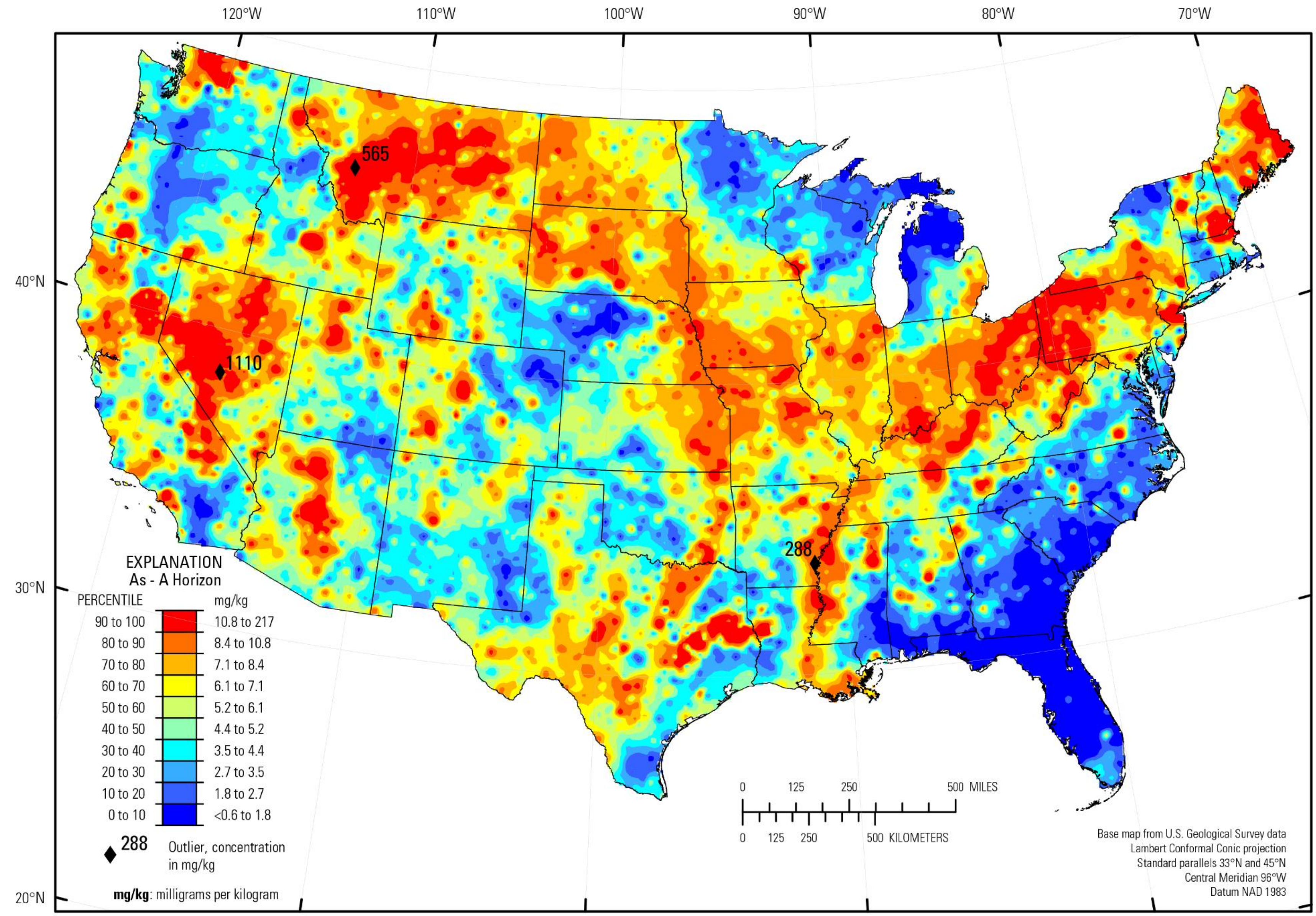


Figure 4. Distribution of Arsenic (As) in the soil A horizon, conterminous United States.

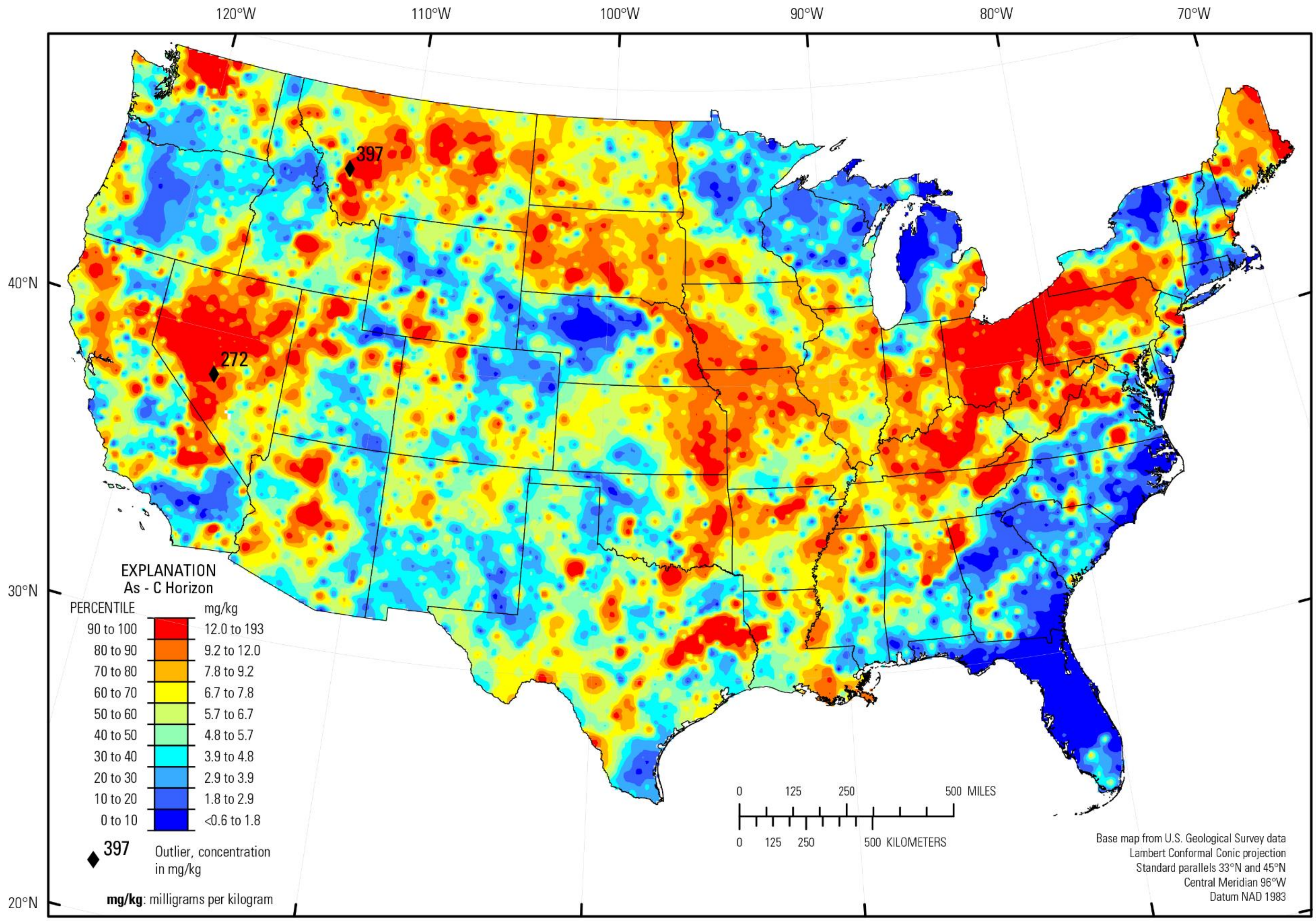


Figure 5. Distribution of Arsenic (As) in the soil C horizon, conterminous United States.

References Cited

Fenneman, N.M., and Johnson, D.W., 1946. *Physiographic divisions of the conterminous U.S.*: U.S. Geological Survey Map, scale 1:7,000,000 (Available at https://water.usgs.gov/GIS/metadata/usgswrd/XML/physio.xml).

Hu, Zhaochu, and Gao, Shan, 2008. Upper crustal abundances of trace elements: A revision and update. *Chemical Geology*, **253** (3–4): 205–221. doi: 10.1016/j.chemgeo.2008.05.010.

Smith, David B., Cannon, William F., Woodruff, Laurel G., Solano, Federico, Kilburn, James E., and Fey, David L., 2013. *Geochemical and mineralogical data for soils of the conterminous United States*: U.S. Geological Survey Data Series 801, 19 p. (Available at https://pubs.usgs.gov/ds/801).

USDA, 2006. *Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin*. U.S. Department of Agriculture Handbook 296. 682 p. (Available at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051845.pdf).

Glossary

alluvial Deposited by a stream or other body of running water

eolian Pertaining to wind

loess Widespread, homogeneous deposits of predominantly eolian silt (with lesser clay and fine sand)

marl Calcium carbonate-rich mud

till Unsorted glacial sediment deposited directly by a glacier